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(54) **Method of saving energy in domestic appliances and appliance with improved energy efficiency**

(57) A clothes dryer comprises a zeolite adsorption system for improved energy efficiency. The system comprises a closed container (K) of zeolite and water in a vacuum. Heating and cooling effects are obtained due to the adsorption and desorption processes and may be

used at various time in the drying cycle. This novel application of adsorption technology requires little space inside the appliance and has a low cost.

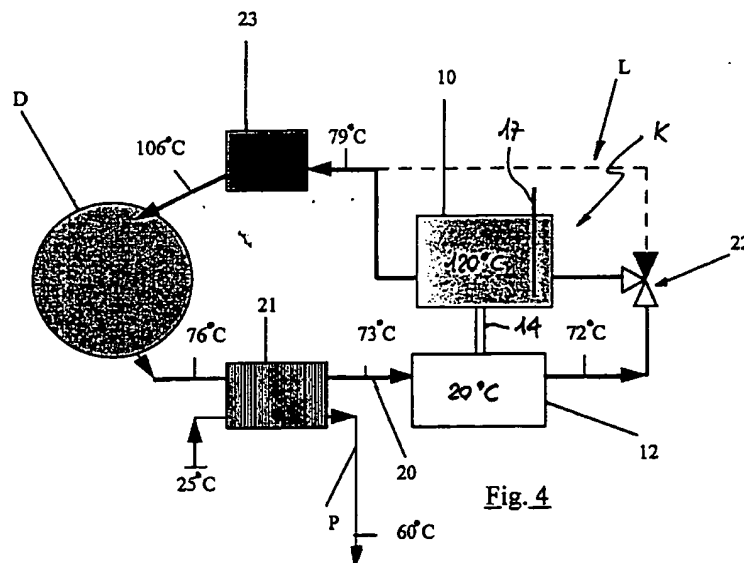


Fig. 4

Description

The present invention relates to a method for saving energy in a domestic appliance and to a domestic appliance in which the above energy savings may be obtained. The present invention relates particularly to a method for saving energy in a domestic appliance in which a fluid flow is used. With the term "fluid" we mean whatever gas, vapor, liquid or mixture thereof which is normally present in a domestic appliance and which takes part to the process performed by the appliance. More particularly, the present invention relates to a clothes dryer having an improved energy efficiency.

Improving energy efficiency of conventional clothes dryers, both air-vented and condenser types, continues to be a challenge for the domestic appliance industry. A system for energy recovery in a clothes dryer has been disclosed in DE-A-3626887. This document describes the use of a zeolite as a desiccant; the moist dryer air passes through a fixed bed of zeolite. The zeolite dries the air and due to adsorption, increases the temperature of the air as well. The above known system has several drawbacks: a large amount of zeolite is needed in order to dry a complete laundry load; the zeolite must be dried after each drying cycle; and the fixed bed of zeolite is easily clogged by the suspended particles present in the air flow.

Object of the present invention is to provide an energy saving method and a domestic appliance which are simple and economical and do not present the above drawbacks.

According to the invention, the fluid is put in a heat-exchange relationship with at least one portion of a closed system in which a solid compound and a volatile compound are contained, the solid compound being capable of adsorbing or desorbing the volatile compound and being capable of generating heat during adsorption and of desorbing the volatile compound when heated, respectively.

With the term "volatile compound" we mean each compound or element which may exist either in liquid or in vapor state.

The closed system according to the invention acts as a heat pump; the resulting heating and cooling effects of the solid compound adsorption heat pump cycle are used in a domestic appliance in order to give time and energy savings, requiring very little space inside the appliance.

Preferably the solid compound is selected in the group consisting of zeolite, alumina, activated carbon and silica gel or mixture thereof. Other materials, generally desiccants or molecular sieves, can be used as well. Among the above materials, zeolite is preferred. Zeolite is a natural substance and is also created industrially in more than 120 different versions. It is primarily used as a substitute for phosphates in the detergent industry. It exists in many forms, including powder and pellets. Zeolite is able to adsorb water vapor and incorporate it into its crystal lattice, at the same time releasing heat. When this occurs in an evacuated closed system such that gases other than water vapor are removed, the water vapor adsorption is so rapid that the water remaining in the evaporator may be cooled below its freezing point due to the removal of its heat of vaporization.

With zeolites, alumina and silica gel the preferred volatile compound is water. With activated carbon methanol or other organic compounds may be used. The choice of the system depends mainly on the average temperature of the fluid flow and of the desired heat of sorption which may vary according to the couple of compounds (solid and volatile). Mixtures of solid compounds and volatile compounds respectively may be used as well.

Preferably the closed system does not contain any gas or vapor which is not condensable (i.e. any gas which does not participate to the adsorption/desorption process). Accordingly, the closed system is preferably under a vacuum.

The present invention is particularly adapted to be applied on a clothes dryer, either a condenser dryer or an air-vented dryer.

Other objects, advantages and novel features of the present invention, as well as details of three illustrated embodiments thereof will be more fully understood from the following description, with reference to the appended drawings in which:

- Figure 1 is a schematic view of a closed system adsorption process according to the invention,
- Figure 2 is a schematic view of a closed system desorption process,
- Figure 3 is a schematic view of a continuous adsorption system according to the invention,
- Figures 4-5 are schematic views of a condenser dryer according to a first embodiment of the invention, in two different working conditions respectively,
- Figure 6 is a schematic view of a condenser dryer according to a second embodiment of the invention, and
- Figures 7-8 are schematic views of an air-vented dryer according to a third embodiment of the invention, in two different working conditions respectively.

In figures 1 and 2 a zeolite adsorption closed system which can be used on a domestic appliance according to the invention is indicated with the reference K. In its simplest form such system consists of an adsorber/desorber 10 (container shaped), which contains zeolite as the solid adsorbent, and an evaporator/condenser 12, which contains water. The system is placed under a vacuum to remove unwanted non-condensable gases. The cooling and heating processes, due to adsorption and desorption, are inherently cyclic and are illustrated in Figure 1 (adsorption process) and

in Figure 2 (desorption process). According to Fig. 1, the zeolite adsorbs water, and consequently cools the evaporator to achieve temperatures of +20°C to -20°C for system pressures of 2500 to 200 Pa. At the same time, the zeolite generates heat to achieve adsorber temperatures of 50°C to 130°C until it is saturated with water at about 30% of its own weight. The adsorption process develops very rapidly, depending largely on the offered passage cross section of a central portion 14 (in the form of a conduit) that connects the water reservoir 12 and the zeolite container 10 rather than the distance between the containers. The process is then reversed during desorption (Fig. 2), where the zeolite is heated by an electric heater 17 to remove the water vapor using temperatures of 150°C to 300°C. Other kinds of heat source may be used for heating the zeolite. During the desorption process the temperature of the condenser 12 may vary between 30°C and 80°C. A valve (not shown) separating the two reservoirs 10 and 12 may be used to control the process.

Continuous cooling may be achieved by using two or more systems in tandem. This is illustrated in Figure 3. Valves 16, operated by an automatic control unit (not shown), are used to shift from one working condition to the other. In the drawings the closed valves are indicated in black, and the open valves are indicated in white. In the configuration shown in Figure 3 a first closed system K' is identified, in which an electric heater 17' heats the zeolite contained in the desorber 10a and in which the water condenses in the condenser 12a. Simultaneously, in a second closed system K'' a zeolite adsorber 10b adsorbs the water coming from the evaporator 12b (a second electrical heater 17'' being off). When the above phases are completed, the black valves 16 are opened, and the white ones are closed. Therefore the zeolite desorber 10a becomes the zeolite adsorber (the electric heater 17' is switched off), and the zeolite adsorber 10b becomes the zeolite desorber. A capillary tube 18 links the condenser 12a with the evaporator 12b. The function of the capillary tube 18 is to provide water to the evaporator 12b at all times. This occurs naturally due to the temperature (and thus pressure) difference between the condenser 12a and the evaporator 12b. The overall energy balance, presuming all the heat output is utilized, is:

$$100\% \text{ heat input} \Rightarrow 130\% \text{ heating output} + 30\% \text{ cooling effect.}$$

The efficiency of the cooling process is only 30%, however, if the heating and cooling effect can both be used, the overall efficiency is 160%. If the 30% heat generated during adsorption is not used, the overall efficiency is 130%.

Figures 4-8 describe the use of zeolite adsorption systems in both condenser and air-vented dryers. The system requires only a means of heating the zeolite, it requires no other energy input and contains no moving parts. Three embodiments are disclosed here. The first embodiment (Fig. 4-5) illustrates the use of a single zeolite adsorption system K operating in a cyclic manner for use in condenser dryers. The second embodiment (Fig. 6) illustrates the use of a dual zeolite adsorption system operating in a continuous manner for use in condenser dryers. The third embodiment (Fig. 7-8) illustrates the use of a single zeolite adsorption system operating in a cyclic manner for use in air-vented dryers.

With reference to Figures 4-5, a single zeolite adsorption system K is incorporated in a condenser dryer comprising a drum D, with the evaporator/condenser 12 placed in the drum airstream 20 after a conventional air-to-air heat exchanger 21. The coolant airflow path through the heat exchanger 21 is indicated with the reference P. The zeolite adsorber/desorber 10 follows the evaporator/condenser 12, and an air bypass loop L with a 3-way valve 22 is included. In Figures 4-5 example operating temperatures are illustrated. These temperatures, as well as the power values mentioned herebelow, are not to be intended as limiting the scope of the invention, but only as example values. The zeolite system has cyclic operation. During the first phase (Fig. 4) adsorption occurs. The evaporator 12 serves as an additional heat exchanger and causes additional water from the drying cycle air to condense. This causes faster drying due to increased moisture removal from the cycle air. The cycle air then passes to the zeolite adsorber 10 (having its electrical heater 17 not activated), which preheats the air as it moves to a dryer electric heater 23. Due to the preheating of the air via the zeolite adsorber 10, the heater 23 is at a reduced power (2250 W) as compared to a normal condenser dryer cycle. This reduces the energy consumption of the cycle. During the second phase (Fig. 5) desorption occurs. The condenser 12 then serves as a heat exchanger, preheating the air before the electric heater 23. In this case the bypass loop L is activated and the zeolite desorber 10 is no longer in the air path. The valve 22 and the electrical heaters 17 and 23 are operated by a central control unit (not shown) of the appliance. The power of electrical heater 23 is reduced (950 W), but no energy is saved because the zeolite must be heated (electric heater 17 activated, power = 820 W) for the desorption process to occur. The energy balance for this case is:

$$100\% \text{ heat input} \Rightarrow 130\% \text{ heating output} + 30\% \text{ cooling effect.}$$

Adsorption and desorption times are dependent upon the system size, i.e. the amount of zeolite and water. The system may be designed to complete a single or multiple adsorption/desorption cycles during a single drying cycle. Energy and time savings are estimated as 20-25% and 2-15% respectively, for varying system sizes. Other variations of the above embodiment include:

a) the zeolite container may be isolated from the air path during both cycles. In this case the energy balance is:

$$100\% \text{ heat input} \Rightarrow 100\% \text{ heating output} + 30\% \text{ cooling effect.}$$

In this case drying time is reduced, which consequently reduces energy consumption. However, energy savings will not be as pronounced as in the preferred method above;

b) the fan for the cooling air can be turned off during adsorption. In this case, during the adsorption phase the evaporator 12 replaces the conventional heat exchanger 21. In this case there is no time savings, but it gives the benefit that no heat during this phase is exhausted to the ambient.

With reference to Fig. 6, a second embodiment of the invention comprises a dual zeolite adsorption system K' and K'' (similar to the system described with reference to Figure 3) which is incorporated in a condenser dryer, with the evaporator 12b and condenser 12a placed in the drum airstream 20, respectively, after the conventional air-to-air heat exchanger 21. A bypass system L' and 3-way valve 25 allows air to then pass over the zeolite adsorber 10b and then to the dryer heater 23. Valve 16 are provided in the central portions 14 of each system in order to shift from one working condition of the closed system to the other and vice versa. The evaporator 12a and the condenser 12b are connected through the capillary tube 18 having the function to provide adequate water flow from the condenser 12a to the evaporator 12b. In Figure 6 also example operating temperatures are illustrated. The zeolite system has continuous operation, so adsorption and desorption occur simultaneously. Thanks to valves 16 (and to an automatic control unit which opens and closes such valves according to a predetermined sequence), the first portions 12a, 12b and the second portions 10a and 10b are shared alternatively by the closed systems K' and K''. The evaporator 12b and condenser 12a have always the same function while the portions 10a and 10b of systems K' and K'' may become desorber or adsorber respectively. The evaporator 12b serves as an additional heat exchanger and causes additional water from the drying cycle air to condense. The cycle air which has reduced humidity then passes over the condenser 12a and the zeolite adsorber 10b, both of which preheat the air before it passes to the dryer heater 23, which is at a reduced power (650 W) than a normal condenser dryer cycle, thus reducing energy consumption (the total power consumption, with the electrical heater of the zeolite having a power of 850 W is about 1500 W). The total instantaneous energy put into the drying airstream is reduced as compared to a normal condenser dryer cycle, being comparable to that of current gentle cycles. Thus, fabric damage is much reduced. Drying time is somewhat reduced as well. Energy and time savings are estimated as 30-40% and 0-11% respectively, for varying system sizes.

A variation of the above embodiment is to allow the fan (not shown) for the heat exchanger cooling air P to cycle on and off. In this case, the evaporator 12b replaces the conventional heat exchanger 21 (however, it alone will not be sufficient for heat removal and thus the fan must cycle on and off). In this case both time and energy savings are reduced, but it gives the benefit that less heat during off-cycling is exhausted to the ambient.

Figures 7-8 illustrate a third embodiment in which a single zeolite adsorption system K is incorporated in an air-vented dryer. A system of three 3-way valves 32 and one 2-way valve 33 plus bypasses allow for the proper air flow. The zeolite system has cyclic operation. During the first phase (Fig.7) desorption occurs. The condenser 12 serves to preheat the air before the dryer heater 23 (which is off in this phase). However, the zeolite container 10 requires energy input (2,85 kW) and so no energy savings are obtained during this phase. During the second phase (Fig.8) adsorption occurs. The evaporator 12 removes waste heat from the exhaust air 34. This waste heat is then recovered in the zeolite adsorber 10 which serves to preheat the air before the dryer heater 23. The energy input rate for the drying air during this phase is the same as a normal cycle without zeolite adsorption, however the actual energy input (electrical heater 23, P = 0,8 kW) to the system is reduced. Total energy savings are estimated at 16%, with no time savings.

The present invention gives a simple and cost effective means for recovering waste heat from appliances in general and particularly from clothes dryers. It requires no energy input and has no moving parts. Through its implementation in any of the aforementioned embodiments, the invention allows for improved energy efficiency and reduced drying time for domestic clothes dryers.

Claims

1. Method for saving energy in a domestic appliance in which a fluid flow is used, characterized in that the fluid is put in a heat-exchange relationship with at least one portion (10, 10a, 12, 12a) of a closed system (K) in which a solid compound may adsorb or desorb a volatile compound, the solid compound being capable of generating heat during adsorption and of desorbing the volatile compound when heated.
2. Method according to claim 1, characterized in that the solid compound is selected in the group consisting of zeolite, alumina, activated carbon, silica gel or mixture thereof.
3. Method according to claim 1, characterized in that the volatile compound is water.

4. Method according to any of claims 1-3, characterized in that the closed system is under vacuum.
5. Method according to claim 1, in which the domestic appliance is a condenser dryer provided with a rotating drum (D) and in which the fluid comprises air and water vapor, characterized in that in a first working condition the fluid (20) leaving the drum (D) is put in a heat-exchange relationship with a first portion (12) of said closed system (K) in which the volatile compound is evaporating in order to cool the fluid flow, this latter being then put in heat-exchange relationship with a second portion (10) of the system (K) in which the solid compound is adsorbing the volatile compound, in order to heat the fluid flow, and in that in a second working condition the fluid flow (20) leaving the drum (D) is put in heat exchange relationship with the first portion (12) of the closed system (K) in which the volatile compound is condensing, in order to heat the fluid flow, in such second working condition the second portion (10) of the closed system (K) being heated in order to desorb the volatile compound from the solid compound.
6. Method according to claim 5, characterized in that the above two working conditions are exploited simultaneously in at least two closed systems (K', K''), each system being provided with valve means (16) in order to share alternatively said first portions (12a, 12b), acting as condenser and evaporator, and said second portions (10a, 10b), acting as desorber and adsorber, connection means (18) being interposed between the condenser (12a) and the evaporator (12b) in order to provide adequate flow of volatile compound from the condenser (12a) to the evaporator (12b).
7. Method according to claim 1, in which the domestic appliance is an air-vented dryer provided with a rotating drum (D) and in which the fluid comprises air and water vapor, characterized in that in a first working condition the fluid flow before entering the drum (D) is put in heat-exchange relationship with a first portion (12) of the closed system (K) in which the volatile compound is condensing in order to heat the fluid flow, in such working condition a second portion (10) of the closed system (K) being heated in order to desorb the volatile compound from the solid compound, and in that in a second working condition the fluid flow before entering the drum (D) is put in heat-exchange relationship with the second portion (10) of the closed system (K) in which the solid compound is adsorbing the volatile compound, in order to heat the fluid flow, the fluid flow leaving the drum (D) being put in heat exchange relationship with the first portion (12) of the system (K) in which the volatile compound is evaporating, in order to cool the fluid flow before discharging it to the ambient.
8. Method according to any of the preceding claims, characterized in that the solid compound is a zeolite and the volatile compound is water.
9. Domestic appliance in which a fluid flow is used, characterized in that it comprises a closed system (K) containing a solid compound and having at least one portion (10, 12) adapted to be put in heat-exchange relationship with the fluid flow, the solid compound being capable of adsorbing or desorbing a volatile compound, the solid compound being capable of generating heat during adsorption and of desorbing the volatile compound when heated.
10. Domestic appliance according to claim 9, characterized in that the solid compound is selected in the group consisting of zeolite, alumina, activated carbon, silica gel or mixture thereof.
11. Domestic appliance according to claim 9, characterized in that the volatile compound is water.
12. Domestic appliance according to any of claims 9-11, characterized in that the closed system (K) is under vacuum.
13. Domestic appliance according to claim 9, particularly condenser clothes dryer comprising a rotating drum (D) and an air circuit in which air leaving and entering the drum is flowing, characterized in that the closed system (K) comprises a first portion (12) adapted to contain the volatile compound and a second portion (10) containing the solid compound and provided with heating means (17), in a first working condition the fluid leaving the drum being adapted to be put in heat-exchange relationship with the above first portion (12) of the system (K) in which the volatile compound is evaporating in order to cool the air flow and then being adapted to be put in heat-exchange relationship with the second portion (10) of the system (K) in which the solid compound is adsorbing the volatile compound in order to heat the air flow, in a second working condition the air flow leaving the drum (D) being adapted to be put in heat-exchange relationship with the first portion (12) of the system (K) in which the volatile compound is condensing, in order to heat the air flow, in such second working condition the heating means (17) being active in order to desorb the volatile compound from the solid compound.
14. Domestic appliance according to claim 13, characterized in that it comprises two systems (K', K'') having a first portions acting as evaporator (12b) and condenser (12a) respectively, each system having a second portion (10a, 10b)

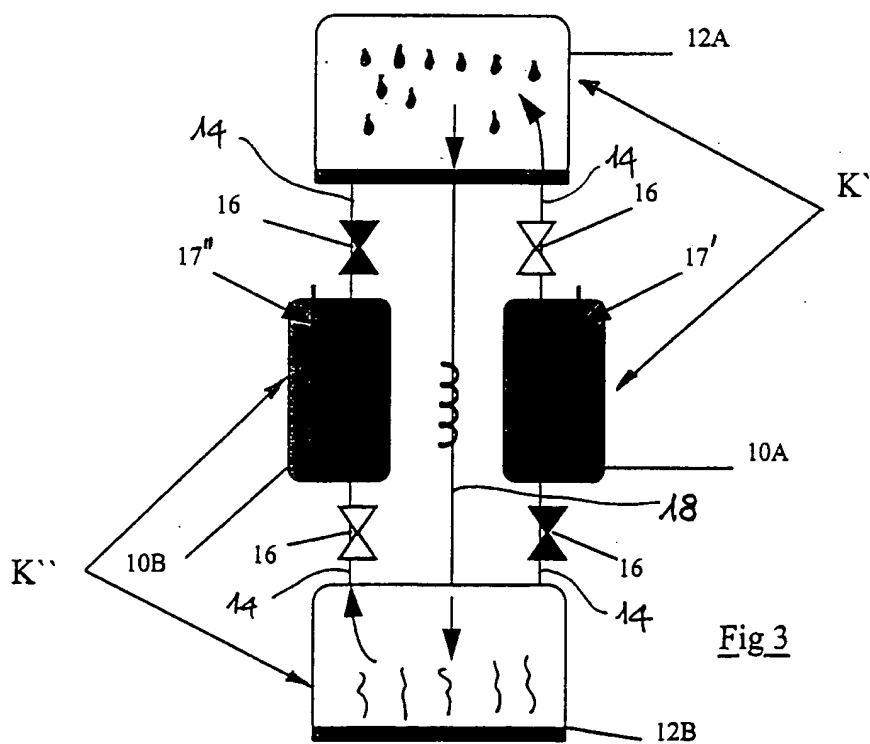
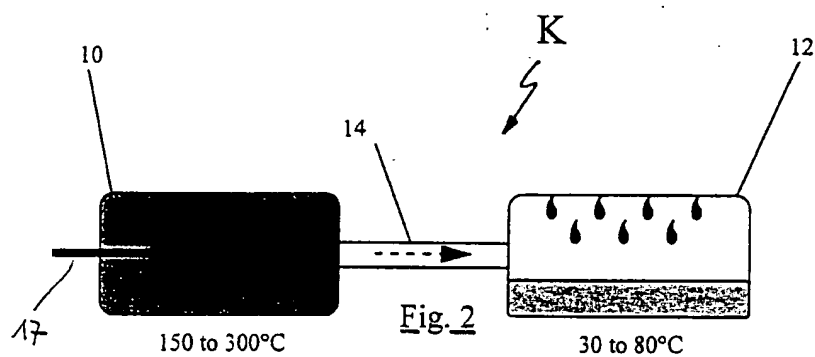
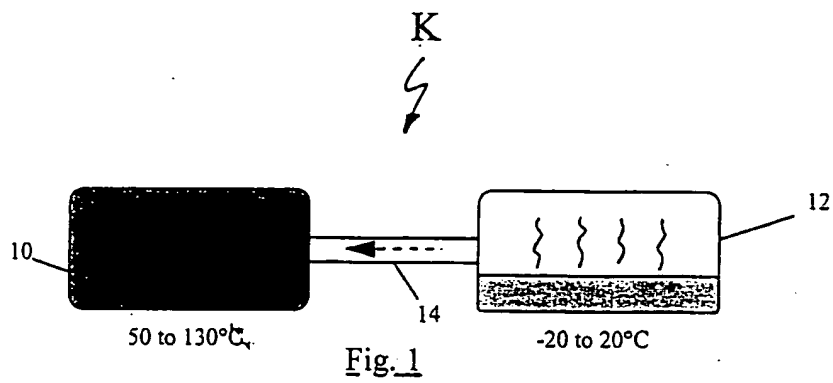
acting alternatively as adsorber or desorber of the volatile compound to or from the solid compound, first valve means (16) being interposed between the first portions (12a, 12b) and the second portions (10a, 10b) in order to shift alternatively from one working condition to the other, and second valve means (25) being provided in the air circuit in order to allow alternatively a heat-exchange relationship between the air flow and one of the second portions (10a, 10b) of the closed systems (K', K''), connection means (18) being interposed between the condenser (12a) and the evaporator (12b) in order to provide adequate flow of volatile compound from the condenser (12a) to the evaporator (12b).

15. Domestic appliance according to claim 14, characterized in that it comprises an evaporator (12b) and a condenser (12a) put in heat exchange relationship with the air flow (20) leaving the drum (D), the evaporator (12b) being connected by means of two conduits (14) to two containers (10a, 10b) respectively, the condenser (12a) being connected by means of two conduits (14) to said two containers (10a, 10b) respectively, valve means (16) being put on each of said conduits (14), said two containers (10a, 10b) containing the solid compound and being adapted to be put by means of said valve means (16) alternatively in heat exchange relationship with the air flow before entering the drum (D) or in a condition apart from the air flow, in such last condition heating means (17) being provided in order to heat the solid compound for desorbing the volatile compound.

16. Domestic appliance according to claim 9, particularly air-vented clothes dryer provided with a rotating drum (D), characterized in that the closed system (K) comprises a first portion (12) which is adapted to be put in heat-exchange relationship alternatively with the air flow entering the drum (D) and with the air flow leaving the drum (D), in the above first flow condition the first portion (12) of the closed system (K) acting as a condenser in order to heat the air flow, a second portion (10) of the system (K) being adapted to be heated in order to desorb the volatile compound from the solid compound, in the above second flow condition the first portion (12) of the system (K) acting as an evaporator in order to cool the air flow leaving the drum (D) before discharging it to the ambient, and the second portion (10) of the system (K) acting as an adsorber of the volatile compound on the solid compound in order to heat the air flow before entering the drum (D), valve means (32, 33) being provided in order to shift from the first flow condition to the second one and vice versa.

17. Domestic appliance according to any of claims 9-16, characterized in that valve means are interposed between the two portions (10, 12) of the closed system (K).

18. Domestic appliance according to any of claims 9-16, characterized in that the solid compound is a zeolite and the volatile compound is water.



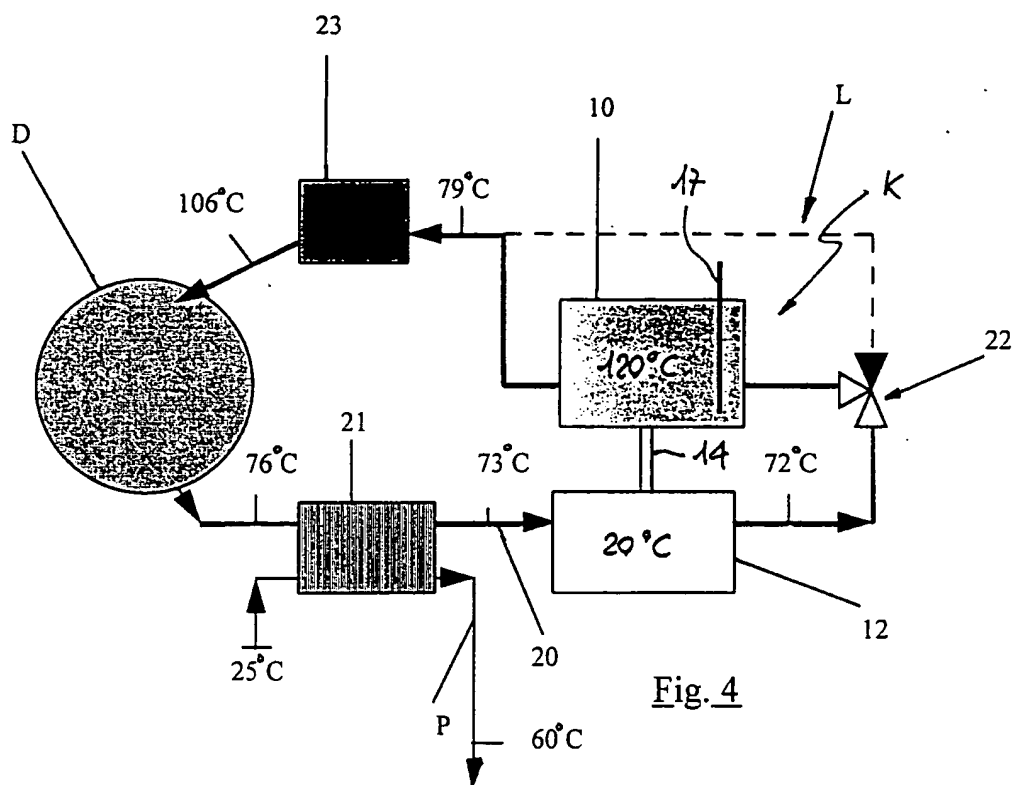


Fig. 4

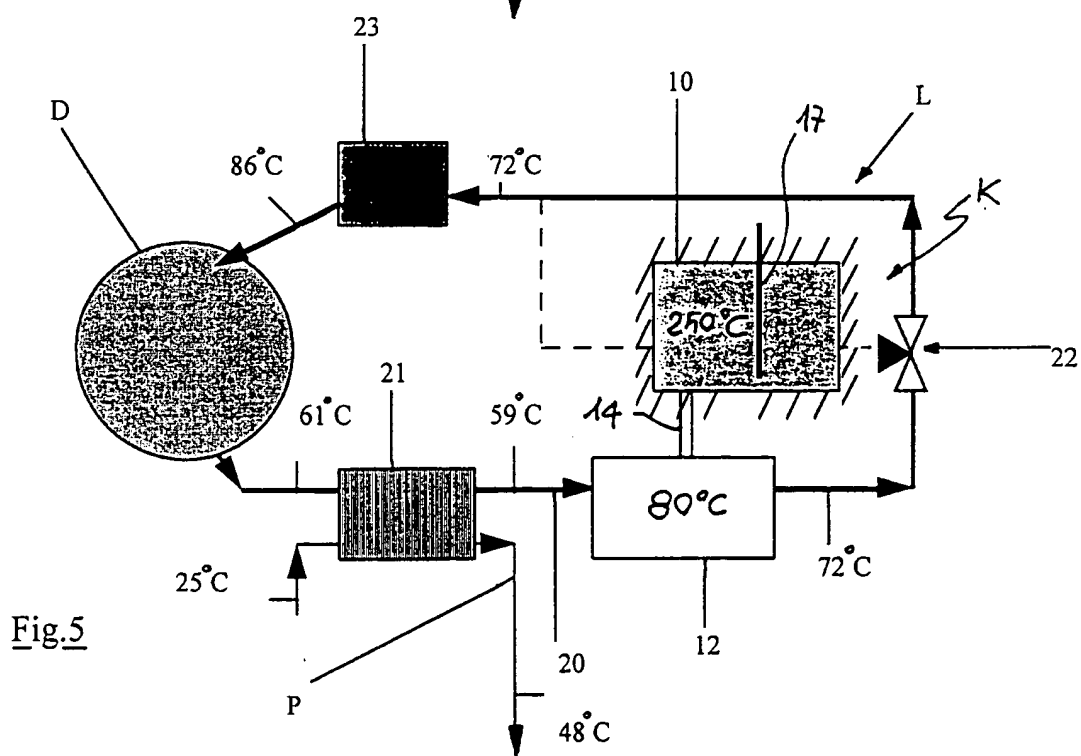


Fig. 5

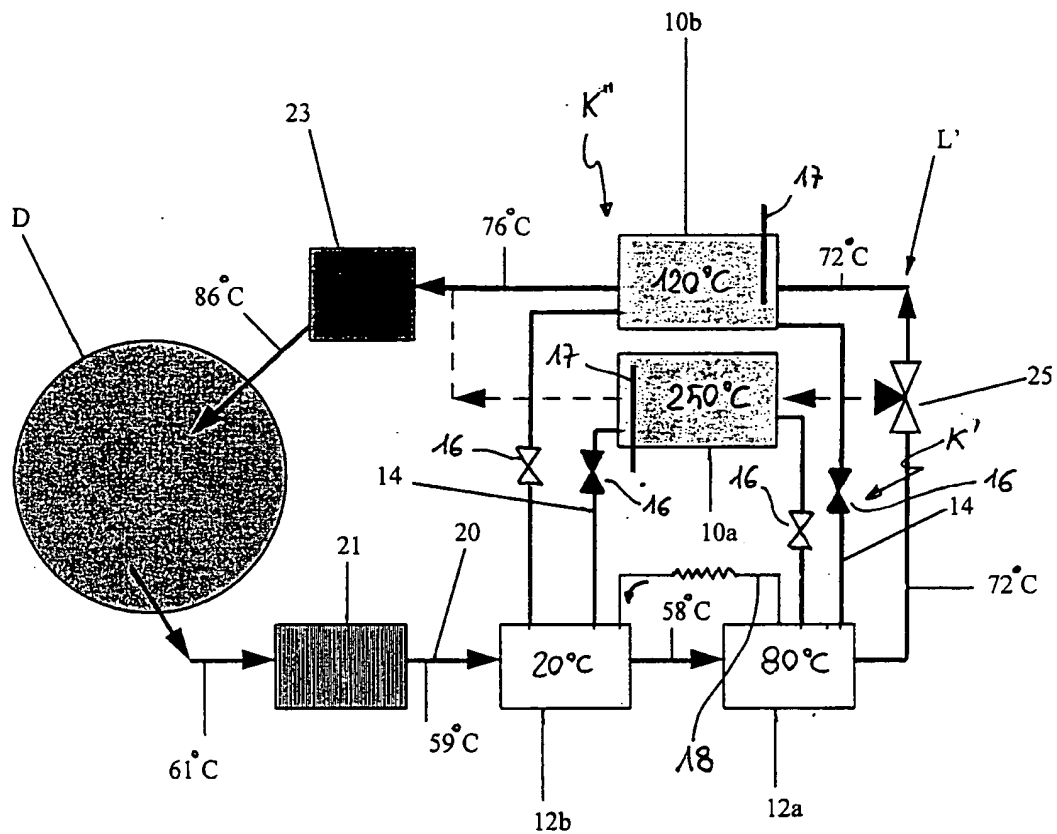


Fig. 6

Fig. 7

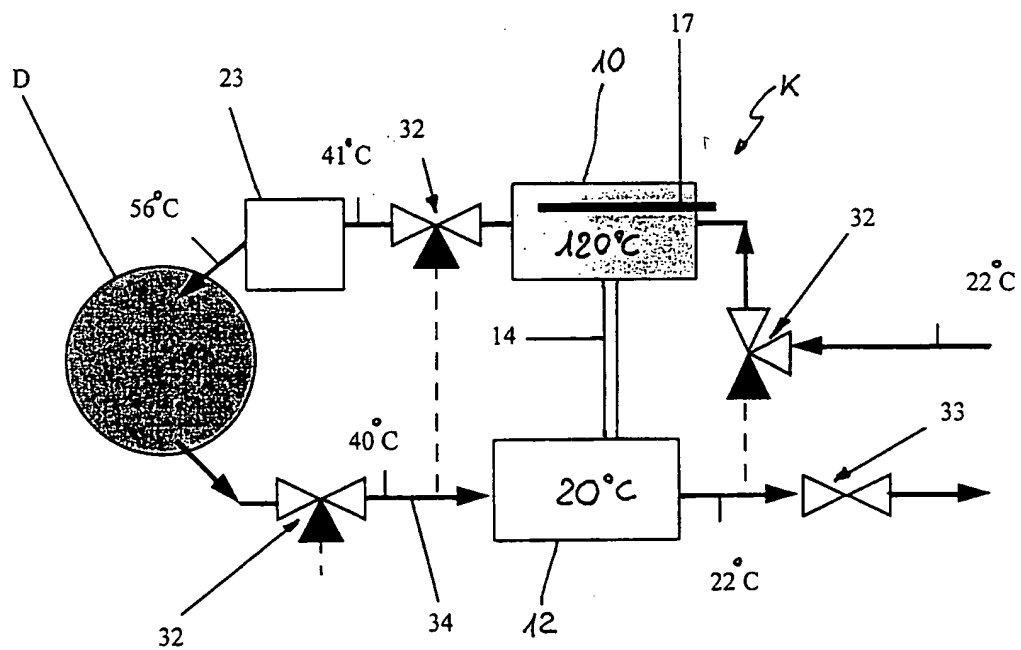
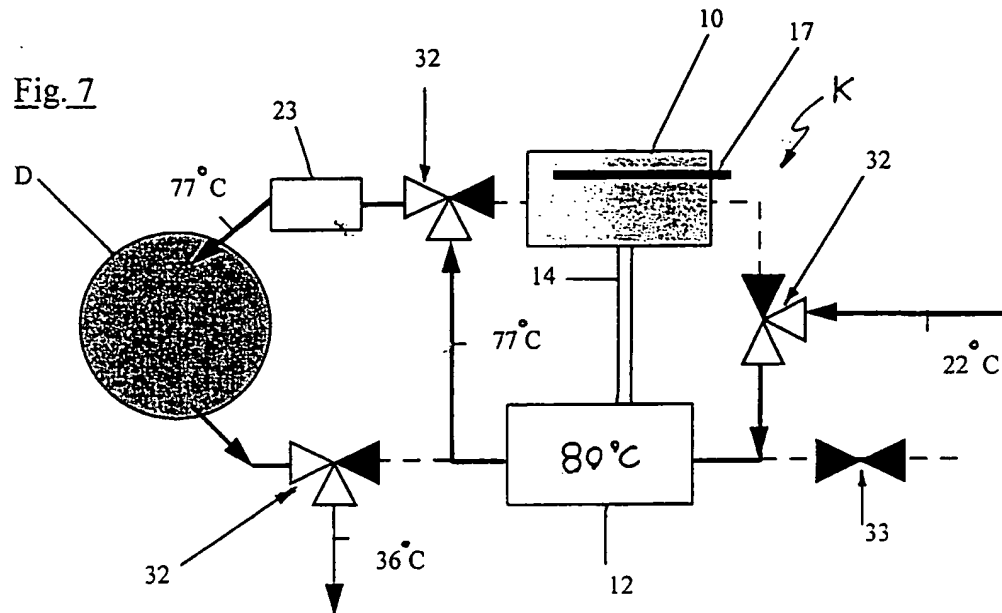


Fig. 8



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 11 9422

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	WO-A-88 09466 (FAIVELEY ENTREPRISES, SOCIETE NATIONALE ELF AQUITAINE) * the whole document *	1-4,9-12	A47L15/48 F25B17/08 D06F58/24 B01D53/26 F26B21/08
Y	DATABASE WPI Week 8636 Derwent Publications Ltd., London, GB; AN 86-234686 XP002001094 & JP-A-61 162 985 (MATSUSHITA ELEC IND KK) , 23 July 1986 * abstract *	1-4,9-12	
Y,D	DE-A-36 26 887 (MIELE & CIE GMBH) * claims; figures *	1-4,9-12	
X	FR-A-2 544 842 (CL.A.BLAIZAT ET AL) * claim 1 *	1-3	
A	EP-A-0 158 326 (F.KAUBEK ET AL) * claim 1 *	1-3	
A	WO-A-85 05170 (D.TCHERNEV) * claims 1-3 *	1-3	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			A47L F25B D06F B01D F26B
Place of search		Date of completion of the search	Examiner
BERLIN		22 April 1996	Cordero Alvarez, M
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